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Upright versus inverted catching and crating end-of-lay hens: a trade-off between animal welfare, ergonomic and financial concerns

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ABSTRACT This study explores upright versus inverted catching and crating of spent laying hens. Both catching methods were compared using a cost-benefit analysis that focused on animal welfare, ergonomic, and financial considerations. Data were collected on seven commercial farms (one floor system and six aviary systems) during depopulation of approximately 3,000 hens per method per flock. Parameters such as wing flapping frequency, catcher bird interaction, incidence of catching damage and hens dead on arrival (**DOA**) were measured and compared between catching methods. Ergonomic evaluations were performed via catcher surveys and expert assessment of video recordings. The wing flapping frequency was lower (3.1 ± 0.6 vs. 4.0 ± 0.5, $P < 0.001$) and handling was gentler (1.9 ± 0.5 vs. 4.4 ± 0.5, $P < 0.001$), both on a 7-point Likert scale, for upright versus inverted catching. However, more person-hours per 1000 hens were required for upright than inverted catching (8.2 ± 3.2 h vs. 4.8 ± 2.0 h, $P = 0.011$), with only wing bruises being significantly less common for upright than inverted catching (1.1 ± 0.6 % vs. 1.7 ± 0.7%, $P = 0.04$). Upright catching was 1.8 times more expensive than inverted catching; compensation for this cost would require a premium price of approximately €0.0005 extra per egg. Ergonomically, both catching methods were considered demanding, although catchers ($n = 29$) preferred inverted catching. In conclusion, this study showed animal welfare benefits of upright vs. inverted catching. Industry adoption of upright catching will depend on compensation of the additional labor costs, adjustments to labor conditions and shorter loading times.

Key words: injury, costs, catcher, manual catching, poultry

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INTRODUCTION

At the end of their productive phase (typically between 65 and 90 wk of age) flocks of spent laying hens face 2 primary fate options: they are either captured, loaded, and transported to the slaughterhouse (more common in densely populated areas such as in the EU) (Gerpe et al., 2021) or subjected to on-farm gassing (more common where farms are located far from the slaughterhouse; Newberry et al., 1999; Turner et al., 2012; Webster and Collett, 2012). Although on-farm gassing of layers may raise ethical questions, catching, crating, loading, and slaughter also cause stress, fear, and injuries (Beuving and Vonder, 1978; Freeman, 1984; Knowles, 1994; Herborn et al., 2015; Gerpe et al., 2021). In general, three main manual catching techniques are used: catching laying hens by either one leg or two legs and carrying them upside down to the crate/container, or upright catching. Catching chickens by two legs reduces fractures compared to catching by one leg (Gregory et al., 1992; Knowles, 1994), but due to the inverted position of the animal, both methods lead to respiratory distress and endanger cardiac activity due to intestinal pressure on the respiratory system and the heart (Nielsen et al., 2022). In upright catching, one or two birds can be held in an upright position with the hand placed over the wings and the abdomen supported

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(Eilers et al., 2009; Kittelsen et al., 2018; Nielsen et al., 2022). This catching method reduces stress in laying hens (Broom, 1990) and broiler chickens (Broom and Knowles, 1989; Kannan and Mench, 1996; Langkabel et al., 2015; Kittelsen et al., 2018). Stress and fear in laying hens can be evaluated by the tonic immobility test (Jones, 1992; Scott and Moran, 1993) and corticosterone levels (Broom, 1986; Broom and Knowles, 1989). For inverted handling, the duration of the tonic immobility was more than two (Jones, 1992) and three times longer (Scott and Moran, 1993), suggesting higher fear levels compared to upright handling (Jones, 1992; Scott and Moran, 1993; Kristensen et al., 2001). Furthermore, the corticosterone level was lower in laying hens caught in the upright position compared to the inverted position, indicating a lower stress level (Broom, 1986; Broom and Knowles, 1989). According to Gregory and Wilkins (1989) violent wing flapping of inverted broiler chickens could cause red wingtips. Upright catching also resulted in fewer wing fractures compared to inverted catching in broiler chickens (Kittelsen et al., 2018). These studies on broiler chickens indicate that animal welfare could be improved with upright catching; however, upright catching takes longer (i.e., fewer birds per catch) and according to catchers it is physically more demanding (i.e., more squatting and more frequent bending over) (Langkabel et al., 2015; Kittelsen et al., 2018). A longer catching process will also extend the period without feed and water and a longer exposure to noise and a poor climate, which could cause stress to the birds (Gregory and Wilkins, 1989; Delezie et al., 2007; Weeks, 2014). Additional drawbacks of upright catching are a higher economic impact due to a prolonged catching process, such as higher personnel costs (Kittelsen et al., 2018). Furthermore, catcher fatigue (Delezie et al., 2007) may set in after a certain time, which has negative effects on concentration and caution and could in turn lead to more animal injuries ((Mitchell and Kettlewell, 2004; Nijdam et al., 2004; Kittelsen et al., 2018). The well-being of the catchers is also important and should be investigated. In general, catching poultry is a physically demanding task, which often leads to injuries and long-term disabilities to the catcher (Arcury and Quandt, 2007). According to GAO (2005), poultry catchers may experience discomfort from spending prolonged periods in uncomfortable positions and performing repetitive movements during catching and loading. These are predictive for developing a musculoskeletal injury (GAO, 2005) and injuries to the upper body (Armstrong et al., 1982; Campbell, 1999; Nowell, 2001; Lipscomb et al., 2006, 2007, 2008; Quandt et al., 2006). Besides the ergonomic issues, the catchers are likely to be soiled with feces and blood from injured chickens while catching (Whittaker, 2005). Layers are caught at night to take advantage of the calmer behavior of the hens (Gerpe et al., 2021) but night work has negative effects on the comfort and safety of the catchers (Knowles and Broom, 1990). The housing systems of laying hens such as cages, aviary systems, and floor housing can also create challenges for ergonomically correct catching (Mitchell and Kettlewell, 2004; Gerpe et al., 2021). During catching, hens can move freely in aviary systems and floor housing (dispersed distribution of hens), possibly resulting in the need to chase them (Knowles and Wilkins, 1998; Gerpe et al., 2021). This is not conducive to the welfare and well-being of the animals nor that of the catchers (Knowles and Wilkins, 1998; Gerpe et al., 2021). In contrast to the substantial body of scientific literature on catching and crating of broilers, literature on catching end-of-lay hens is much more scarce. Moreover, to the best of our knowledge, no studies have yet assessed upright catching of laying hens with a focus on animal welfare, ergonomics, and economics. This lacuna was addressed in the present study. The three main objectives of the study are as follows: first, to compare upright versus inverted catching of spent hens on commercial farms (one floor system and six aviary systems) with respect to animal welfare, efficiency, costs, and opinions of the catchers; second, to simulate the ergonomics of upright and inverted catching and compare them in an experimental setting; and third, to combine the results on commercial farms and the simulations to generate a cost-benefit analysis of both catching methods.

MATERIALS AND METHODS

Study on Commercial Laying Hen Farms (Assessment of Animal Welfare)

The study was conducted on 5 commercial laying hen farms in Belgium and two in the Netherlands from October 2022 to May 2023. On six farms the hens were housed in a multi-tier (or aviary) system; on one farm the hens were housed in a single-tier (floor) system. Per farm, one flock of end-of-lay hens was assessed (average age: 94 wk, Dekalb White (four times), Isa Brown (three times)). In this study, two professional catching companies active in Belgium and the Netherlands were involved. The catching companies were paid to catch, crate and load a total of approximately 3,000 hens using the upright method. The remaining layers were caught with the inverted method (i.e. how they usually catch and load the birds, that is, grasping one leg per hen and holding 3 hens upside down in each hand). Approximately 3,000 caught hens (from all flocks) per catching method were followed up from catch through post-slaughter, the exact number of hens caught per flock for inverted and upright catching is indicated in Table 1. Just before catching, the catching teams were given a brief demonstration and instruction, using a graphical poster with a corresponding explanation (Figure 1). Flocks under study were examined postmortem (**DOA**) at Ghent University and in the evisceration zone at the slaughterhouse on the day after catch and transport.

On-farm Measurements A team of trained and validated researchers conducted on-farm observations and measurements of the experimental group caught using the upright method as well as a more or less equal number of hens caught using the inverted method. For the measurements, 2 flocks started with inverted

Table 1. General information about the participating laying hen flocks such as the number of laying hens caught inverted (I) and upright (U), the number of the catchers, the order of the catching method, the number of scored laying hens for inverted and upright catching on-farm, and the number of scored laying hens for inverted and upright catching in the slaughterhouse.

Flock	# layers I	# layers U	# of catchers	Order	# scored layers (on-farm)	# scored layers (slaughterhouse)
1	3240	4383	22	U/I	U: 84 & I: 32	U: 3174 & I: 2628
2	4320	3600	32	U/I	U: 118 & I: 45	U & I: 2565
3	3888	4752	33	I/U	I: 63 & U: 86	I & U: 2520
4	2754	1836	13	U/I	U: 126 & I: 68	U & I: 1690
5	3420	3420	19	U/I	U: 124 & I: 48	U & I: 2332
6	3024	3024	13	I/U	I: 111 & U: 146	I & U: 2520
7	2940	2940	24	U/I	U: 85 & I: 31	U: 2190 & I: 2267

catching and five flocks started with upright catching. Transport containers (n = 3 flocks) or crates (n = 4 flocks) were marked according to the catching method that was used. This enabled a team of researchers to collect data on both groups of hens at the slaughterhouse.

Monitoring of individual hens per catching method from catch to crate was performed by two trained researchers. They were instructed how to follow up on the hens per method in each flock, the exact number of hens for inverted and upright catching is mentioned in Table 1. The number of scored hens depended on the number of catchers (the more catchers were working, the faster the process went, and thus the fewer opportunities researchers had to observe separate catching events). The exact number of catchers is shown in Table 1. For each hen, specific indicators were measured: 1) the wing flapping frequency (7-point Likert scale with score 1 = least flapping, 4 = neutral, and 7 = most flapping) during the time the catcher held the hen (Table 2), 2) catcher bird interaction (7-point Likert scale with score 1 = soft handling, 4 = neutral, and 7 = rough handling) (Tables 2 and 3) whether the catching method was applied correctly (Yes/No) and the reason if this was not the case (Tables 3 and 4) whether or not the hen had escaped or slipped out of the catcher's hold (Yes/No).

At the end of catching and crating the experimental group, the total process was scored by both researchers on a 7-point Likert scale for noise (score 1 = quiet, 4 = neutral, and 7 = loud) (Table 2), chicken behavior (score 1 = calm animals, 4 = neutral, and 7 = restless animals) (Table 2), and crating efficiency (score 1 = efficient, 4 = neutral, and 7 = not efficient) (Table 2). Entrapment of hen body parts (numbers) were noted

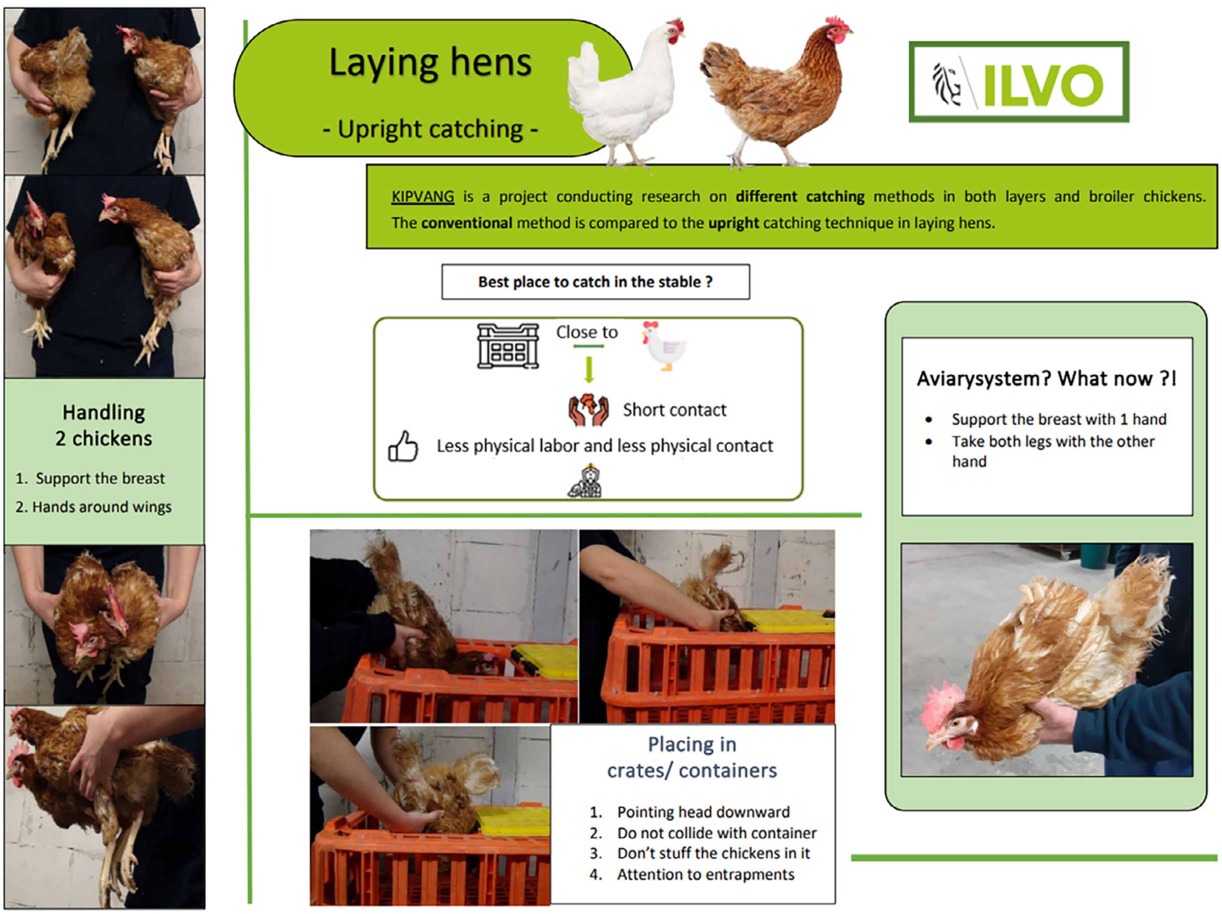

Figure 1. Poster including guidelines for catching laying hens upright with specific information for catching upright in an aviary system.

Table 2. Explanation of the different scores on the 7-point Likert scale according to (1) wing flapping frequency, (2) catcher bird interaction, (3) noise during the catching process, (3) the chicken behavior during the catching process, and (5) the crating efficiency during the catching process.

Score	Wing flapping	Catcher bird interaction	Noise	Chicken behavior	Crating efficiency
1	no flapping	calm and slow	no noise	don't resist	catching the chickens properly and placing them correctly in the container/crate and good cooperation between catchers (always)
2	flapping with the wings a few times	calm and carefully	occasional noise	resist a little bit and calm	catching the chickens properly and placing them correctly in the container/crate and good cooperation between catchers (between more than half of the time and always)
3	flapping with the wings between a few times and half of the time	calm and less efficient	between occasional noise and noise half of the time	resist a little bit and not calm	= catching the chickens properly and placing them correctly in the container/crate and good cooperation between catchers (more than half of the time)
4	flapping with the wings half of the time	calm and efficient	noise half of the time	reacting towards catcher, but not in a stressful way	catching the chickens properly and placing them correctly in the container/crate and good cooperation between catchers (half of the time)
5	flapping with the wings more than half of the time	quick and loud	noise more than half of the time	reacting towards the catcher in a stressful way	catching the chickens properly and placing them correctly in the container/crate and good cooperation between catchers (between half of the time and occasional)
6	flapping with the wings between more than half of the time and always	quicker and louder	between noise more than half of the time and always	birds flying away and try to escape	catching the chickens properly and placing them correctly in the container/crate and good cooperation between catchers (occasional)
7	always flapping	brutal and throwing	always noise	totally in panic while making a lot of noise	not efficient (not catching the chickens properly and placing them correctly in the container/crate and no good cooperation between catchers)

Table 3. Wrong applications of the method for upright and inverted catching.

Upright	Inverted (by one leg)
Holding chicken by the wrong body part	Holding chicken by the wrong body part
Both hands are not around the wings	/
Breast is not supported	/
Holding one chicken correctly & one chicken wrong	More than 3 chickens in one hand
Catching chicken by the leg while escaping	Catching chicken by the leg while escaping
Catching chicken by the wing while escaping	Catching chicken by the wing while escaping

per container/crate per catching method. The number of caught hens (number of hens per container/crate multiplied by the number of containers/crates per catching method and per flock(*)), the number of catchers (counted the catchers during catching, crating, and loading), and how long it took to catch and crate both batches (start of catching the first chicken until placing the last chicken in the crate/container) were recorded. These data were used to calculate the number of person-hours per 1,000 hens:

$$Total\ person - hours\ (h) = Number\ of\ catchers$$
$$*total\ duration\ of\ the\ catching\ method\ (h)$$

Table 4. Summary of the on-farm assessment after inverted and upright catching of spent laying hens at seven farms, expressed as mean ± SD.

	Inverted	Upright	*P*-value
Wing flapping frequency (1-7)	4.02 ± 0.50	1.94 ± 0.50	**<0.001**
Catcher bird interaction (1-7)	4.41 ± 0.50	3.06 ± 0.60	**<0.001**
Duration of catching 1000 chickens (person-hours performed) (h)	4.75 ± 2.00	8.17 ± 3.17	**0.011**
Incorrect application method (%)	45.43 ± 32.30	22.25 ± 10.10	0.12
• > three chickens per hand	38.70 ± 7.46	NA	0.08
• Wrong body part	0 ± 2.21	6.71 ± 2.21	
• Hands not around the wings	NA	19.90 ± 8.46	
• Breast is not supported	NA	5.75 ± 4.10	
• Holding one chicken correct & one chicken wrong	NA	0.91 ± 1.17	
Chicken slips out of the catcher's hands (%)	0.78 ± 1.40	0.22 ± 0.40	0.31
Evaluation catching process (1-7)			
• Noisiness	4.79 ± 1.15	4.57 ± 1.21	0.08
• Behavior of chicken	4.79 ± 0.95	4.29 ± 0.57	0.16
• Efficiency	3.29 ± 1.50	4.29 ± 0.76	0.17

Significant *P*-values ($P < 0.05$) are indicated in bold and P-values between 0.05 and 0.10 are underlined.

$$Total\ person - hours\ per\ 1000\ hens = \frac{\text{Total person} - \text{hours (h)}}{\text{Number of hens caught}(*)} * 1000$$

After loading the experimental groups, the catchers were surveyed to gather their opinions on upright versus inverted catching in terms of animal welfare and ergonomics. The written survey was presented in Dutch, English, and Polish to ensure full comprehension and accurate answers. Catchers were first asked about physical pain, that is, whether they had much more/more/similar/less/much less pain in the neck, shoulders, upper back, arms, lower back, and knees when catching upright compared to inverted catching. In addition, they were asked to indicate whether upright catching (as compared to inverted catching) was strongly more tiring/more tiring/equally/less tiring/strongly less tiring, and whether the hens were more restless/restless/equally/calmer/much calmer. Finally, they were asked to score their perceived learning curve for upright catching as very rigid/rigid/equally/smooth/very smooth. In total, 29 catchers completed at least a part of the survey.

Measurements at the Slaughterhouse The same groups of chickens for inverted and upright catching (Table 1), were observed in two slaughterhouses (slaughterhouse one, n = 5 flocks, CO_2 stunning and slaughterhouse two, n = 2 flocks, electrical stunning) in Flanders. The average transport time was 50 ± 35 minutes, ranging from 9 to 120 min. A single person collected the chickens who arrived dead in the slaughterhouse (dead on arrival, [**DOA**]) for each catching method. Necropsies on DOA hens were performed by a certified pathologist to evaluate whether the cause of death was related to the catching, crating, and loading process or if it was attributed to an underlying pathology that made the animal unfit for transport. In the evisceration zone (after defeathering), three observers counted the number of injuries, including bruises on and fractures of the wings (observer 1) and legs (observer 2), and bruises on the wing tip and breast (observer 3). Only fresh bruises (≥ 1 cm without yellow or green discoloration and with red discoloration) and fresh fractures (with or without protruding bone, accompanied by redness/blueness; a bruise combined with a fracture was only counted as a fracture) were taken into account to exclude injuries sustained before the catching, crating, and loading process. Postmortem fractures as result of handling in the slaughterhouse (e.g., plucking machine) were excluded, these were recognized by the absence of bleeding or bruising. Multiple injuries of the same type (bruises or fractures) per body part (legs, breast, wings, and wing tips) were counted as one injury.

The assessments were conducted six times per experimental group, with each session lasting 3 min per catching method with a pause of 30 s between the observations (in total 18 min). The average line speed was 145 laying hens per minute (range 140 − 155 laying hens per minute) and the hens followed up for inverted and upright catching per flock is mentioned in Table 1. The prevalence of different types of injuries based on specific body parts was calculated using the following formula (Jacobs et al., 2017):

$$Prevalance = \frac{\text{Number of animals with at least one injury on a specific body part}}{\text{Line speed} * \text{Number of observed minutes}} * 100$$

Statistical Analysis For data processing of the on-farm measurements, R (version 4.2.1) was used to apply a linear mixed model with the catching method as a fixed effect and the farm as a random effect. Subsequently, a type III ANOVA analysis was performed to determine P-values for the differences between catching methods. A P-value < 0.05 was assessed as significant. The different assumptions for a linear model were checked before applying the ANOVA tests: the residuals of the models had to be normally distributed and homoscedastic (based on a graphical assessment using histogram, QQ plot of the residuals and a residual versus fitted plot).

Simulations to Determine Workload by a Certified Ergonomist

In addition to the catcher survey, catcher ergonomics were observed in an experimental setting. Several methods were used, namely 1) the NIOSH method (National Institute of Occupational Safety and Health) (Ashley, 2015), 2) the ART tool (Assessment of Repetitive Tasks) (HSE − ART too, 2024a), 3) MAC tool (Manual handling assessment charts) (HSE − ART too, 2024b), and last 4) a survey of the catchers.

In an experimental setting, three test persons (not habitual catchers) were observed while they caught and loaded hens using the upright and inverted method. The experimental setting was a commercial aviary farm and 4 infrared cameras (front view: camera 1, side view: camera 2 and 3, top view for asymmetry: camera 4) recorded the movements of the test persons. All movements were performed in the dark to mimic a realistic setting. Markers were placed on the lateral side of the body of the test persons to calculate joint angles. Markers were placed at the malleolus lateralis (ankle), lateral epicondyle of the femur (knee), trochanter major (hip), acromion (shoulder), lateral epicondyle humerus (elbow), and ulna styloid process (wrist) (Figure 2). Each test person caught five to six laying hens using the inverted method or two hens upright per simulated catching event; this was repeated three times. Catching was performed on three height levels (tier 1: 0 cm, tier 2: 84 cm, and tier 3: 115 cm) of the aviary system; for each level, the chickens were put in crates at three heights (Level 1: 53 cm, Level 2: 84 cm, Level 3: 115 cm). In total each catcher performed 27 actions per catching method (3x catching, on 3x height levels, at 3x crate heights).

The NIOSH method is used to evaluate a lifting motion (revised lifting equation, RLE). The outcome of the RLE is the maximum weight to be lifted or the

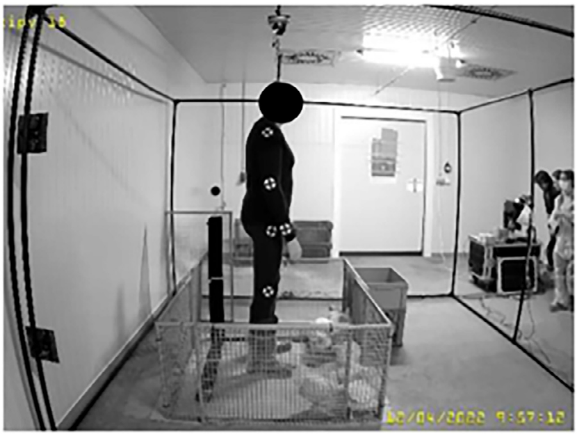

Figure 2. Setting of markers placed on the body of the test person to identify the different body parts for analysis.

recommended weight limit (RWL). When the RWL is exceeded, the risk of injury and lower back pain increases (Waters et al., 1993). The formula used to evaluate the movements of the catchers is:

$$Recommended\ weight\ limit$$
$$= 23\ kg\ x\ HM\ x\ VM\ x\ DM\ x\ AM\ x\ CM\ x\ FM$$

with HM: Horizontal multiplier, VM: Vertical multiplier, DM: Distance multiplier, AM: Asymmetric multiplier, FM: Frequency multiplier, and CM: Coupling multiplier (Waters et al., 1993). The equation also uses a weight constant. This is the maximum weight to be lifted under optimal conditions when all parameters are assigned a factor of one. Based on various criteria, the weight constant was fixed at 23 kg (Waters et al., 1993; Howard, 2020).

The ART tool applies to repetitive work and is used for risk analysis (expression of the risk of upper limb overload) (HSE – ART too, 2024a).

The categories used by the ART tool are:

- GREEN: Low risk level
- AMBER: Medium risk level - examine task closely
- RED: High risk level - quick action required

An ergonomist examined the recorded videos of the test persons based on the following categories: arm movements, repetition, force applied to the hand, an inefficient posture of head/neck, arms, back, hands, fingers, grip, breaks, work pace, duration, and psychosocial factors (HSE – ART too, 2024a). A score was assigned for each category using the above color codes. From this, a total score was obtained between zero to 11 (low risk), between 12 to 21 (medium risk), and >22 (high risk).

The MAC tool evaluates the risks of injury due to lifting and carrying (HSE – ART too, 2024b). It indicates the factors that need to be adjusted to control the indicated risks.

The categories applied by the MAC tool are:

- GREEN: Low-risk level - although the risk is low, consider the exposure levels for vulnerable groups such as pregnant women, disabled people, recently injured, young or inexperienced workers
- AMBER: Medium risk - examine task carefully
- RED: High-risk level - prompt action required, this may expose a significant portion of the workforce to the risk of injury
- PURPLE: Unacceptable level of risk - such actions may pose a serious risk of injury and should be corrected

An ergonomist examined the recorded videos of the test persons based on the following aspects: load weight/frequency, distance between hand and lower back, vertical lifting zones, torso rotation and side bending, postural restrictions, load grip, floor surface and environmental factors ("HSE – MAC tool,"). A score was assigned to each aspect using the color codes above. From this, a total score was obtained between zero to 11 (low risk), between 12 to 21 (medium risk), and >22 (high risk).

Cost-Benefit Analysis

The costs of various catching methods were considered, including labor costs, loader (forklift) cost, truck loading cost, and the duration of catching 1,000 hens (person-hours). Standard prices applicable on the commercial farms during the experiments were used for calculating the costs of upright versus inverted catching (e. g. labor: €40/h/person, forklift: €70/h, and transport: €75/h). The total cost for catching, crating, and loading (seven times in total) was calculated for upright and inverted catching. The total labor cost for catching and loading 1,000 hens per method, and the total person-hours (the overall number of hours worked) for each catching method were calculated. The total amount of labor expressed in person-hours for 1,000 hens per catching method was determined using the following formulas:

$$Total\ person - hours\ (h) = number\ of\ catchers$$
$$*\ total\ duration\ of\ the\ catching\ method\ (h)$$

$$Total\ person - hours\ for\ 1000\ hens\ (h)$$
$$= \frac{Total\ person - hours\ (h)}{Number\ of\ hens\ caught(*)} * 1000$$

$$Total\ labor\ cost\ per\ 1000\ hens\ (€)$$
$$= Total\ person - hours\ for\ 1000\ hens(h)$$
$$*\ standard\ price(€/h)$$

To calculate the costs for the forklift and loading the truck, the following formulas were applied:

$$\mathit{Total\ duration\ for}\ 1000\ \mathit{hens}\ (h) = \frac{\mathit{Total\ duration\ of\ the\ catching\ method}\ (h)}{\mathit{Number\ of\ hens\ caught}(*)} * 1000$$

$$\mathit{Total\ forklift\ cost\ per}\ 1000\ \mathit{hens}(€) = \mathit{Total\ duration\ for}\ 1000\ \mathit{hens}\ (h) * \mathit{standard\ price}\ (€/h)$$

In addition to costs, benefits were also compared between inverted and upright catching, specifically in terms of animal welfare (flapping frequency [score 1−7], catcher bird interaction [score 1−7], and reduction of animal injuries [bruises and fractures, in %]), and well-being of the catcher (ergonomics and safety). Ultimately, the additional cost per egg (€) was determined, based on an average poultry flock caught at the prices valid during the study period.

RESULTS

Study on Commercial Laying Hen Farms (Assessment of Animal Welfare)

Statistically significant differences of upright compared to inverted catching included 1) a lower average wing flapping frequency (1.94 vs. 4.02 on a 7-point scale), 2) a better average of catcher bird interaction (3.06 vs. 4.41 on a 7-point scale), and 3) a longer average duration of catching 1,000 chickens (8.17 h vs. 4.75 h) (Table 4). A non-significant but higher average percentage was observed of catching hens at the wrong body part (0% vs. 6.71%), and less noise (4.79 vs. 4.57 on a 7-point scale) for upright compared to inverted catching (Table 4).

Assessments at the slaughterhouse revealed no significant difference in the number of injuries of laying hens between inverted and upright catching (7.9% vs. 7.1%, Table 5). Injuries scored at the slaughterhouse showed no significant differences between catching methods, with the exception of bruises on the wings, with 0.6% fewer bruises for upright catching (Table 5). No significant differences between catching methods were found for any other specific injuries (wing fractures, bruises on wingtips, bruises on the breast, bruises and fractures on the legs), nor for the total prevalence of injured hens (Table 5).

The number of DOA hens was very similar for inverted and upright catching (0.23 ± 0.09% vs. 0.22 ± 0.18%; $P = 0.96$) (Table 5). The necropsies revealed that all (100%) or most (92%) DOA hens had no traumatic injuries whether caught upright or inverted, respectively. Traumatic lesions were observed only in three inverted caught DOA hens; in each of these an underlying disease process was present. In nearly all cases, an underlying systemic pathology (coelomitis, metastatic adenocarcinoma, chronic suppurative salpingitis, and spotty liver disease) was detected that most likely led to a general weakening of the animal (potentially not fit for transport). In addition, four (upright) and six (inverted) of the dead hens were cachectic or too small. In four DOA hens (caught inverted), no significant lesions were observed macroscopically that could explain the mortality of the animal.

Table 5. Summary of the assessment at the slaughterhouse after inverted and upright catching of spent laying hens at 7 farms, expressed as mean ± SD.

	Inverted	Upright	P-value
Average injuries (%)	7.9 ± 1.9	7.1 ± 2.7	0.15
Injuries (%):			
Bruises wing	1.73 ± 0.70	1.13 ± 0.63	**0.04**
Fractures wing	0.06 ± 0.12	0.06 ± 0.07	0.99
Bruises wingtip	3.66 ± 1.65	3.48 ± 1.81	0.55
Bruises breast	0.95 ± 0.24	1.04 ± 0.25	0.55
Bruises leg	1.52 ± 1.00	1.41 ± 1.32	0.78
Fractures leg	0.01 ± 0.02	0.01 ± 0.02	0.60
DOA (%)	0.23 ± 0.09	0.22 ± 0.18	0.96

Significant P-values ($P < 0.05$) are indicated in bold and P-values between 0.05 and 0.10 are underlined.

Simulations to Determine Workload by an Ergonomist

NIOSH According to the NIOSH method, catchers of laying hens are allowed to lift a maximum of 1 kg and 1.5 to 2 kg under unfavorable and favorable conditions, respectively (favorability of conditions is determined by the asymmetry of the catcher's body relative to the animal and the height relative to the ground when catching the hens). Considering the average weight of laying hens, it is therefore recommended to lift a maximum of two hens at a time for both inverted and upright catching methods.

ART For the ART tool, each aspect was assigned a specific color (Table 6). All total scores exceeding 22 indicate a dangerous situation. The scores for inverted catching were higher compared to upright catching (Test person 1: 26 vs. 20, Test person 2: 26 vs. 20, Test person 3: 25 vs. 20). These differences can be attributed to the differences in force exerted by the hand and the posture of the back and head/neck during upright catching, which were rated as less stressful than inverted catching (Table 6).

MAC For both inverted and upright catching, the distance between the hand and lower back, vertical lifting zones, torso rotation, sideways bending (only in inverted catching), posture restrictions, grip on the load, floor surface, and environmental factors all received the worst score possible. The total score according to the MAC tool is three points lower for upright catching compared to inverted catching (19 vs. 22). This is due to lower scores for weight and frequency of load, as well as torso rotation and sideways bending (Table 7).

Survey of Catchers When comparing upright vs. inverted catching, the catchers reported more pain/similar pain in different body parts (neck (48% vs. 45%),

Table 6. Assessment of ergonomics of laying hen catchers for both inverted and upright catching using the ART Tool, with GREEN: Low-risk level, AMBER: Medium risk level - examine task closely, and RED: High-risk level - quick action required.

Category	Inverted	Upright	Explanation
Arm movements	Amber	Amber	Frequent (e.g. regular movement with some pauses)
Repetition	Green	Green	Similar motion pattern of the arm and hand is repeated 10 times per minute or less
Force on hand	Red	Amber	Red: Almost all the time (80% or more) Amber: About half the time (40-60%)
Head/neck posture	Amber	Green	Amber: Bent or twisted part of the time (e.g. 15–30%) Green: In an almost neutral posture
Back Posture	Red	Amber	Red: Bent forward, sideways, or twisted for more than half of the time Amber: Bent forward, sideways, or twisted part of the time
Arm posture	Red	Red	Raised away from the body more than half of the time
Wrist posture	Green	Green	Almost straight/in a neutral position
Hand/finger grip	Green	Green	Power grip or do not grip awkwardly
Breaks	Amber	Amber	Two hours to less than three hours
Work pace	Amber	Amber	Sometimes, it is difficult to keep up with the work
Other factors	Red	Red	Gloves affect gripping and make handling more difficult; The tool causes discomfort/cramping of the hand/fingers; catchers are exposed to cold/draughts; Lighting level is inadequate
Duration	Red	Red	Four to eight hours

Table 7. Assessment of ergonomics of laying hen catchers for both inverted and upright catching using the MAC tool with GREEN: Low-risk level, AMBER: Medium risk, and RED: High-risk level.

Category	Inverted	Upright	Explanation
A Load weight/frequency	Amber	Green	Amber: The weight carried is > 10 kg & the duration can vary between five s & two min Green: The weight carried is < 10 kg & the duration can vary between five s & two min
Hand distance from the lower back	Red	Red	Torso upright. Arms fully outstretched. Hands far from the low back. Upper arms angled away from torso and torso bent forward.
Vertical lift zones	Red	Red	Hands at floor level or below. Hands at head height or above.
Torso twisting and sideways bending	Red	Amber	Red: Torso both twisted and bent sideways. Amber: Torso twisted or bent sideways.
Postural constraints	Red	Red	Severely restricted posture.
The grip on the load	Red	Red	There are no handles or grips and a rough or smooth surface. In addition, palm, pinch, or fingertip grip or force is used to hold objects together.
Floor surface	Red	Red	Slippery (greasy, oily, wet, icy) or much debris or soft or unstable or severe damage.
Environmental factors	Red	Red	Light conditions are dark and air quality is poor (ammonia and dust).

shoulders (21% vs. 68%), upper back (28% vs. 62%), arms (3% vs. 83%), lower back (38% vs. 28%), and knees (48% vs. 24%)). The great majority of catchers indicated that upright catching is strongly (45%) or more tiring (45%) compared to inverted catching. The majority of respondents (n = 28) perceived hen behavior as similar during both types of catching (47%). The majority of the catchers found that upright catching is very rigid (33%) to rigid (37%) to learn compared to inverted catching (Figure 3).

Cost-benefit Analysis

All the results are expressed per 1,000 laying hens unless indicated otherwise.

For upright catching an additional 3.4 person-hours were needed compared to inverted catching, and with the same workforce the task took 70% longer (4.8 h vs. 8.2 h, $P < 0.011$). The average labor costs for upright catching were 1.8 times higher than for inverted catching (€369.4 vs. €206.5). Cost of using the forklift and loading the truck was 1.6 times higher for upright catching compared to inverted catching (€27.8 vs. €17.5 and €29.8 vs. €18.8). Consequently, the average additional cost for upright catching compared to inverted catching of 20,000 laying hens is €3478 (€7984 vs. €4506); or €0.0005 per egg (€0.0011 vs. €0.0006) (Table 8).

The ergonomics assessment revealed that both inverted and upright catching are too physically demanding for the catchers. The catchers indicated that

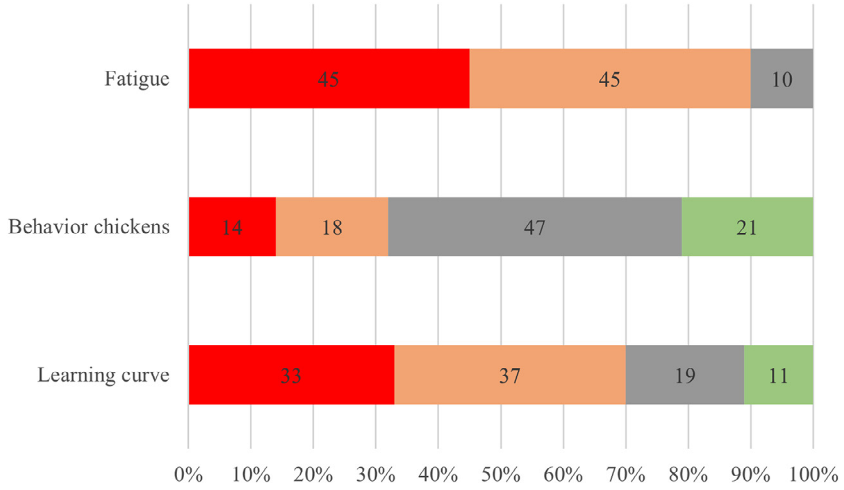

Figure 3. Fatigue (n = 22 respondents) with red: strongly more tiring, orange: more tiring, grey: equally, light green: less tiring, dark green: strongly less tiring, behavior of the laying hens (n = 28 respondents) with red: more restless, orange: restless, grey: equally, light green: calmer, dark green: much calmer, and the learning curve (n = 27 respondents) with red: very rigid, orange: rigid, grey: equally, light green: smooth, dark green: very smooth, for upright vs. inverted catching indicated by catchers of laying hens, with red the worst score and green the best score.

Table 8. The average costs, additional cost and ratio of labor, forklift, loading the truck, the total cost of catching 1,000, 20,000 and one laying hen(s), and the price per egg for inverted (C) and upright (U) catching.

	Inverted (€)	Upright (€)	Additional cost U vs. C (€)	Ratio U/C
Labor	206.5	369.4	162.9	1.8
Forklift	17.5	27.8	10.3	1.6
Loading truck	18.8	29.8	11.0	1.6
Total cost 1000 laying hens	242.8	427	184.2	1.8
Total cost 20,000 laying hens	4856	8540	3684	1.8
Total cost one laying hen	0.24	0.43	0.19	1.8
Price per egg*	0.0007	0.0012	0.0005	1.8

*Total amount of egg per hen in her production cycle (360).

Table 9. Cost and benefit analysis of inverted and upright catching laying hens with the comparison between costs, ergonomics, and animal welfare.

		Inverted	Upright
Costs (€)	Average cost catching 20,000 laying hens	4856	8540
	Cost per egg	0.0007	0.0012
Ergonomics	Expert	–	–
	Catchers	+	-
	Safety catchers	-	–
Animal welfare	Wing flapping frequency (1-7)	4.02	1.94
	Catcher bird interaction (1-7)	4.41	3.06
	Injuries - bruises on the wings (%)	1.73	1.13

upright catching is more exhausting than inverted catching (Table 9).

DISCUSSION

In this study, several aspects of catching and crating of spent laying hens using either inverted or upright catching were compared, in terms of animal welfare, ergonomic workload, and cost. The results indicate that upright catching represents welfare advantages (less wing flapping, gentler handling, and fewer injuries) for the hens but implies additional labor (costs) with an ergonomically similar load as inverted catching.

This on-farm study indicated a lower wing flapping frequency for upright catching compared to inverted catching and the catchers demonstrated a more gentle approach when catching the laying hens upright. The better score for wing flapping can be explained by the fact that with the upright method the hands cover the wings and this results in calmer chickens (Kannan and Mench, 1996; Kittelsen et al., 2018; de Lima et al., 2019; Nielsen et al., 2022). Besides, there is a possibility that birds will flap their wings less because they are restricted if there are more hens caught at the same time. Multiple studies have shown that gentle handling has positive effects on animal welfare, including less stress, fear and injuries (Barnett and Hemsworth, 1989; Gregory and Wilkins, 1989; Scott and Moran, 1992, 1993; Knowles and Wilkins, 1998; Cockrem et al., 2010). However, the interviewed catchers indicated that upright catching is more exhausting than inverted catching. It is important to consider that the response rate was rather low (depending on the question, response rate was only 22 to 29 out of 148 catchers) because there was a strong language barrier and most catchers exhibited a lack of motivation to fill out the survey. They were reluctant to perform upright catching, which could have influenced the answers given in the survey. According to Kittelsen et al. (2018), upright catching takes longer and this results in more fatigue of the catchers, which can indicate that they were more reluctant to perform upright catching and to fill out the survey. Furthermore, Millman et al. (2017) mentioned that poultry catching is a hard job and the catchers want to finish the job as quickly as possible, so they are not really in favor of upright catching because it takes longer. The catcher's subjective experience during upright catching and their attitude towards it is important, which should be taken into account when analyzing other results (e.g. measurements during catching and loading, measurements in the slaughterhouse and the ergonomics). Especially in aviary systems, the catchers indicated a higher risk of injury during upright catching than inverted catching because during upright catching they need both hands to hold the chicken and thus have no hand free to hold on to the aviary system for support. In this study, it was possible that laying hens were handed from catchers on top of the tier to catchers on the ground in the aviary system, but this was balanced between upright and inverted catching because a complete compartment per catching method was caught. The intention of the present study was to have a balanced sequence of catching methods, but practical constraints prevented this. Consequently, experiments began three times more frequently with upright catching (± 3000 hens) than with inverted catching (± 3000 hens) (five vs. two times). This disparity could potentially impact the results, as the catchers could be more tired during the second catching method and the increased activity among laying hens as the catching process continued could lead to more difficulties in catching and potentially more injuries (Mitchell and Kettlewell, 2004; Nijdam et al., 2004; Delezie et al., 2007; Kittelsen et al., 2018). In other studies examining the ergonomics of factory workers engaged in repetitive manual tasks, chicken catchers are found to be at a higher risk compared to workers in a cleaning products factory (Shokri et al., 2015) and face a similar risk level to workers in a plastic tube production factory (Sukwika and Harjanto, 2024). Overall, chicken catchers are as susceptible to injuries as factory workers, a group recognized as being at risk (McGill, 2016).

The assessments at the slaughterhouse revealed that upright catching resulted in fewer injuries, but the difference was only statistically significant for bruises on the wings. Depopulation of laying hens is associated with an incidence rate of 8.1% for severe injuries (e.g., fractures and muscle damage) (Gerpe et al., 2021) and an average of 24% of hens with broken bones (13 - 41%) (Gregory and Wilkins, 1989). In broiler chickens, fewer wing fractures were found for upright catching compared to inverted catching (Kittelsen et al., 2018). The incidences of this study were rather low and could perhaps be linked to the presence of external observers which could have influenced the manner of catching.

Based on the video images of simulation of both catching methods, the ergonomist concluded that both inverted and upright catching are too physically demanding for the catchers. The NIOSH, ART, and MAC methods were employed to assess catcher ergonomics. According to NIOSH, inverted catching requires catchers to get closer to the ground, resulting in slightly higher lifting compared to upright catching, where the entire body of the animal is captured. This reduces the lower lifting weight, but upright catching increases the frequency of lifting as it implies a maximum of two hens per catch instead of five to six. This was not tested due to the experimental setting. ART and MAC scores indicate a slightly better ergonomics of upright catching. Both methods are labor-intensive, involving frequent arm movements, sustained force on the hands, asymmetric motions, bending, challenging grips, and potential discomfort; these all indicate the need for further research to alleviate the ergonomic load of the catching process. Within the present study, conclusive evidence of ergonomic workload is difficult to provide due to the limitations of the experimental design such as the use of non-professional test persons instead of catchers (not willing to cooperate), no expert observations of ergonomics during the catching and loading process, and evaluation of a limited number of non-calibrated movements. Catchers self-reported that upright catching is more tiring and time-consuming, in accordance with Kittelsen et al. (2018). Upright catching is a new technique and is unfamiliar to the catchers, which may have contributed to the negative attitude towards this approach. The negative attitude can be linked to the fact that upright catching takes longer and this will result in more fatigue for the catchers and in general they want to finish the catching process as quickly as possible (Millman et al., 2017; Kittelsen et al., 2018). It is plausible that with the increased practice of the upright method, catchers may get more used to it and may report more positively in the future. Additionally, training and attitude of animal handlers plays a significant role in the quality of their handling (Cransberg et al., 2000; Pilecco et al., 2013; Grandin, 2015; Ceballos et al., 2018). Effective training and communication can result in better identification of the risks of animal welfare linked to the handling procedures such as preventing chickens from escaping the grasp of catchers or from the container/crate (Newberry et al., 1999; Grandin, 2015; Ceballos et al., 2018).

Upright catching takes longer to complete than inverted catching, thus the number of hens that are transported as a unit should be reduced or the catching team expanded. In the absence of such changes, animal welfare could therefore be negatively impacted due to longer duration of stress and an extended period of feed and water deprivation (Kittelsen et al., 2018). On the other hand, smaller transport units would require additional drivers and would result in more (greenhouse gas) emissions. Expanding the catching team presents two challenges: 1) there is a shortage of catchers in the poultry industry, and 2) a larger team may negatively affect efficiency of the catch and may involve additional costs (Kittelsen et al., 2018). These costs were not included in our financial estimates as the composition of the catching teams in our study was the same for upright and inverted catching.

Under the conditions of the present study, the total cost for catching 20,000 laying was 1.8 times higher using the upright instead of the inverted method. The farmer would need to receive a premium price of €0.0005 per egg to compensate for this additional cost. The higher price may be passed on to consumers, which raises questions about their willingness to pay for improved animal welfare. Studies suggest that consumers prefer products from animals with a higher animal welfare status, but that the extent of their willingness to pay may be influenced by the information provided and their general product knowledge (Napolitano et al., 2008; Coleman et al., 2022).

Large-scale on-farm depopulation via gassing represents one alternative to catching and loading spent laying hens. This method is used in regions located far from slaughterhouses, such as certain areas in Canada, the US and Scandinavia (Turner et al., 2012; Berg et al., 2014). When a concentration of 45% CO_2 is reached, the laying hens faint within 20-30 seconds and after two minutes, the animal is declared dead (Newberry et al., 1999; Webster and Collett, 2012; Turner et al., 2012). This method has advantages and disadvantages. Advantages are the minimal contact between handlers and birds, which optimizes biosecurity and reduces stress for the birds (Yalçin et al., 2004; Turner et al., 2012). Transportation to the slaughterhouse and withdrawal of food and water are no longer necessary and the environment of the chickens does not change (Yalçin et al., 2004). Disadvantages could induce respiratory distress (gasping and headshaking), stress experienced during the gassing process, and lack of ability to process the chickens for consumption (Milsom, 2001; Raj et al., 2006).

In conclusion, this study confirmed the previously observed animal welfare benefits from the upright catching method (less wing flapping, better handling, and fewer wing bruises) over inverted catching as mentioned in previous studies of broiler chickens. Future research should investigate catching entire flocks using the upright method, including assessments of truck waiting times, catching and crating procedures, slaughtering schedules, costs, and personnel considerations. Before this new method can be adopted in practice, the additional labor cost will need to be compensated, labor conditions will need to be addressed and the loading time will need to be minimized.

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DISCLOSURES

The authors declare no conflicts of interest.

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